# Data Report on a Benthic Survey Conducted near Kent Island, British Columbia

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# DATA REPORT ON A BENTHIC SURVEY CONDUCTED NEAR KENT ISLAND, BRITISH COLUMBIA

by

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## ABSTRACT

Sutherland, T.F., Levings, C.D., Petersen, S.A., Sinclair, D., Jepps, S., Gillard, B., Knight, J., McPhie, R., Walton, P., Lessard, J., McGreer, E., and Taekema, B. 2005. Data report on a benthic survey conducted near Kent Island, British Columbia. Can. Data Rep. Fish Aquat. Sci. 1166: v + 27 p.

A grab sampling survey was carried out a finfish site situated on the southwest side of Kent Island located in Queen Charlotte Strait, British Columbia. Replicate grab samples were also collected at a nearby reference site. The sediment samples were analyzed for sediment grain size, total nitrogen and carbon content, trace-metal concentration, and macrofaunal abundance. A SCUBA survey was also carried out approximately 6 months prior to the grab sampling to assess the fish, flora, and epifaunal communities present in the nearshore environment. The data resulting from these surveys are presented in this report.



## RESUMÉ

Sutherland, T.F., Levings, C.D., Petersen, S.A., Sinclair, D., Jepps, S., Gillard, B., and Knight, J., McPhie, R., Walton, P., Lessard, J., McGreer, E., and Taekema, B. 2005. Data report on a benthic survey conducted near Kent Island, British Columbia. Can. Data Rep. Fish Aquat. Sci. 1166: v + 27 p.

Une campagne d'échantillonnages ponctuels ponctuels a été effectuée sur un site piscicole se trouvant au sud-ouest de l'île Kent, dans le détroit de la Reine-Charlotte (Colombie-Britannique). Une campagne de contrôle parallèle par échantillonnages ponctuels a été effectuée Des échantillons de référence ont également été recueillis de la même façon sur un site de référence se trouvant à proximité. Les sédiments recueillis échantillons ont été soumis à des analyses granulométriques, chimiques ( et à des analyses visant à établir la teneurs en azote, et en carbone et, la concentration de en métaux en traces) et biologiques (abondance de la macrofaune). l'abondance macrofaunique du sédiment. Environ six mois avant la campagne d'échantillonnage ponctuel, des relevés un programme d'étude en plongée autonome ont avait été effectués exécuté pour caractériser recenser les communautés piscicoles, floristiques et épifauniques présentes à proximité du rivage. Ce rapport présente orte sur les résultats données obtenues.

## INTRODUCTION

Environmental impacts may be associated with fish farm activities through changes in sedimentation rates of organic particulate matter, sediment oxygen demand and sulphide reduction, and benthic community structure (Fisheries and Oceans Canada 2004). The relationship between organic enrichment and the behavioural responses of benthic macrofauna have been reviewed by Diaz and Rosenberg (1995), while the recovery of benthic macrofaunal populations influenced by organic enrichment associated with fish farm activities has been documented by Lu and Wu (1998). This report provides a data summary of a suite of sediment environmental parameters as well as benthic macrofauna taxa observed at a salmon netpen location southwest of Kent Island, British Columbia. This farm had been in operation for a short period (March 13 to August 31, 2002) and consisted of twelve 24 x 24 m netpens in two rows of six (held 1.008 M Atlantic salmon smolts). The documentation of this data set may be useful in providing information for potential changes in macrofaunal communities associated with this level of production under current conditions in the British Columbia environment.

## SITE CHARACTERISTICS

Kent Island is part of the Walker group of islands located in Queen Charlotte Strait, British Columbia (Figure 1). The farm site is situated on the southwest side of Kent Island next to Bolivar Passage in a steep sided bay which drops to 100 m in depth within 600 m of the shore. The bay is approximately 735 m wide and 400 m long. Reference stations were located on the southeast side of Kent Island where Ripple Passage and Shelter Passage meet. The depth beneath the netpen system ranged from approximately 38 m to 90 m while the depths of the reference stations ranged from 60 m to 70 m (Table 6). A report by Brooks (2002) describes the benthic substrate consisting of bedrock, boulders, large cobble, and patches of sand near the proposed tenure site with predominantly sandy substrates observed 1600 m from the site. In addition, rich macroalgal beds and invertebrate communities, including Northern abalone (*Haliotis kamtschatkana*), were observed in the highly diverse habitat in the nearshore environment.

## BENTHIC SURVEY DESIGN

The staff of the Habitat Enhancement Branch (HEB) and Conservation and Protection Division (C&P) made plans to conduct a benthic grab survey at the fish farm site at Kent Island. Advice was sought from the Science Branch (C.D. Levings) regarding the sampling design of the grab survey. Sediment samples were collected along the perimeter of the netpen system as well as in a central location between the two netpen arrays. Three reference stations were located on the southwest side of Kent Island where Ripple Passage and Shelter Passage meet.

## MATERIALS AND METHODS

### SCUBA SURVEY

Shelley Jepps, Bryce Gillard, and Joe Knight carried out a reconnaissance SCUBA survey along the nearshore (896 metres) on May 7, 2002. Two transects made up of 3 dives were surveyed along the shore in a zig zag pattern between highwater and 20 feet of depth as measured by the diver's depth gauge. The primary diver recorded observed fauna and flora on an underwater slate and made general habitat observations. The secondary diver used a Sony Digital Handycam (model DCR-TRV17 NTSC) with an Amphibico Dive Buddy housing to video the habitat and species present. A species list of fish, invertebrates, and algae was generated from observations made along this dive.

Due to the noted presence of abalone during the reconnaissance SCUBA survey, a second set of SCUBA surveys were conducted between May 28$^{th}$ and 31$^{st}$, June 10$^{th}$ and 12$^{th}$ of 2002 with the specific intent of estimating abalone population at the site. This survey was conducted using methodology outlined in Lessard et al. (2002). Transect locations for both dives are shown in Figure 2.

### ROV SURVEY

An ROV survey of the site was conducted with a Deep Ocean Phantom HD2 between June 4 and 6, 2002. The GPS locations of the four corners of the netpen structure were recorded using a Garmin II Plus (model GR-145-00214) from fisheries support vessels on June 4 (Port Hardy 1) and June 5 (Chimaera IV). A series of nine transects was then filmed with the ROV around the perimeter of the netpen structure as well as northward and southward along the predominant current in the area. The locations of these transects relative to the netpen structure are shown in Figure 3. Observations of habitat and fauna within the tenure were made from these transects by Shelley Jepps.

### GRAB SURVEY

On September 12$^{th}$ and 13$^{th}$, 2002, three Ponar grab (0.04 $m^2$) samples were collected by HEB and C&P staff at the Kent Island aquaculture facility. Although the individual nets had been removed from the two netpen arrays, walkway structures and 2 large predator nets remained in place. Only one Ponar grab (Station S-17) was successfully deployed from the netpen walkways using a portable capstan winch on September 12, 2002, due to net entanglements during deployments. As a result, perimeter sampling was resumed on September 13, 2002, with the use of a capstan gear puller and a 733-Hurricane Zodiac rigid hull inflatable alongside the netpen structure. Two more grab samples were successfully obtained using this technique (Stations S-9 and S-10).

When the Ponar grab was retrieved, the contents were carefully placed into a bucket and three 150 mL subsamples were removed from the intact surface layer using a plastic scoop. Each of these samples were placed in 180 mL cylindrical amber glass sample jars with plastic lids and stored in a cooler for geotechnical and chemical analyses. The remainder of the grab sample was then washed through a 1.0 mm sieve using screened surface seawater for macrofaunal analysis. The sieved samples were then placed in 1 L plastic sample jars and preserved with a solution of 10% buffered formalin.

The preserved samples were later transferred into isopropyl alcohol prior to laboratory analysis.

Further grab sampling was carried out using a Van Veen grab (0.1 $m^2$) aboard the B.C. provincial vessel, Grizzly Coast, along with the support of the Ministry of Water, Land and Air Protection (MWLAP) on October 1, 2002. Once the grab samples were retrieved, four subsamples were removed from the surface layer and homogenized in a plastic container before being split into three 180 mL amber sample bottles according to MWLAP monitoring protocols. Ten sediment grab samples were collected along the netpen perimeter (Figure 5), while 3 reference samples were collected on the opposite side (southeast) of Kent Island. The macrofauna samples were sampled in a similar manner to those described above.

## LABORATORY ANALYSIS

The surficial sediment subsamples were delivered to Environment Canada's Pacific Environmental Science Centre (PESC), North Vancouver, British Columbia, for trace-metal, total nitrogen, total carbon and particle size analysis. The preserved macrofauna samples were sent to Biologica Environmental Services Ltd., Victoria, British Columbia, for invertebrate enumeration and general sample description.

### Trace Metal Analysis

A subsample of sediment from one of the three sample jars collected at each station was removed and placed in a 16 dram plastic vial with a snap closure, ¼ to ½ full. These subsamples were then analyzed according the PESC SEDMET Method V 6.0, using an Optima 4300 Inductively Coupled Plasma Emission Spectrometer (PerkinElmer Life and Analytical Science, Woodbridge, ON). This procedure tests for content of:, aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, phosphorous, potassium, selenium, silicon, silver, sodium, strontium, sulphur, tin, titanium, vanadium, and zinc.

### Total Carbon and Nitrogen Analysis

The total nitrogen concentration of the sediment samples was determined using the PESC TN Method V 2.0 automated, colorimetric, persulphate digest cadmium/copper reduction. Percent total carbon determinations were made by Pacific Soil Analysis Inc., Richmond, British Columbia. Determinations were made using a 12% $CaCO_3$ standard and performed in a 2500° F oven.

### Particle Size Analysis

The particle size analysis on the benthic sediment samples was carried out according to the Ocean Dumping Extra Points format (Soilcon, 2003). Each sample was first put through a 2.0 mm dry sieve. The portion <2.0 mm was then wet sieved through 1.0 mm, 0.5 mm, 0.25 mm and 0.125 mm sieves and finally the remaining solution was stirred and 20 mL subsamples removed with a volumetric pipette at predetermined time intervals to determine the soil fractions less than 0.063 mm, 0.004 mm and 0.002 mm. The particle size data was also merged and presented in the standard Ocean Dumping

format which consists of four broader categories: <0.004 mm, 0.004 - 0.63 mm, 0.63 - 2.00 mm, >2.00 mm.

**Macrofauna Analysis**

For the macrofauna analysis, a Rose Bengal stain was added to the samples to stain organisms pink and help facilitate the sorting process. Five mL fractions of each sample were sorted in a gridded dish using a dissection microscope (10 to 30 x magnification) removing all organisms with forceps. Each dish was sorted at least twice. For sorting quality assurance, the debris was retained and a portion from each jar was spread in a 22.5 x 32.5 cm white pan and examined under a dissection microscope at 12 x magnification. If greater than 2 organisms were recovered the entire sample was resorted and subjected to another spot check. A sorting efficiency was calculated based on the results of the resorts. The entire sample was sorted in this manner. In terms of taxonomic verification, sorting identifications of the observed organisms were verified by a taxonomist. When incomplete specimens were present only anterior portions were counted. Colonial organisms such as bryozoa, hydrozoa and cnidarians were counted as colony fragments, not as specimens or individuals. Identified organisms were stored in 70% ethanol in labelled vials.

**Debris Description**

Estimates of the retained debris portions of the preserved samples were provided by Biologica Environmental Services Ltd. Wood, mineral material and shell fragments were measured using 0.5 cm increments, while mineral material was measured using 0.2 cm. If the mineral portion of the debris was <0.2 cm it was identified as sand, silt or clay depending on a subjective judgement by the observer. Materials > 0.2 and < 0.5 cm were indentified as gravel (<0.5 cm) and gravel larger than 0.5 cm was measured to the nearest 0.5 cm.

## ACKNOWLEDGEMENTS

We would like to thank the Pacific Environmental Science Centre (PESC), Pacific Soil Analysis Inc, Soilcon Laboratories Ltd., and Biologica Environmental Services Ltd. for analysis of various chemical, geotechnical, and biological sediment components, respectively. We would also like to thank the crew of the Grizzly Coast for their assistance during the field survey. Thanks to Scott Morrison for providing the maps and Beth Piercey for her assistance in editing this report. Funding for this project was provided by the HEB, C&P, and Science branches.

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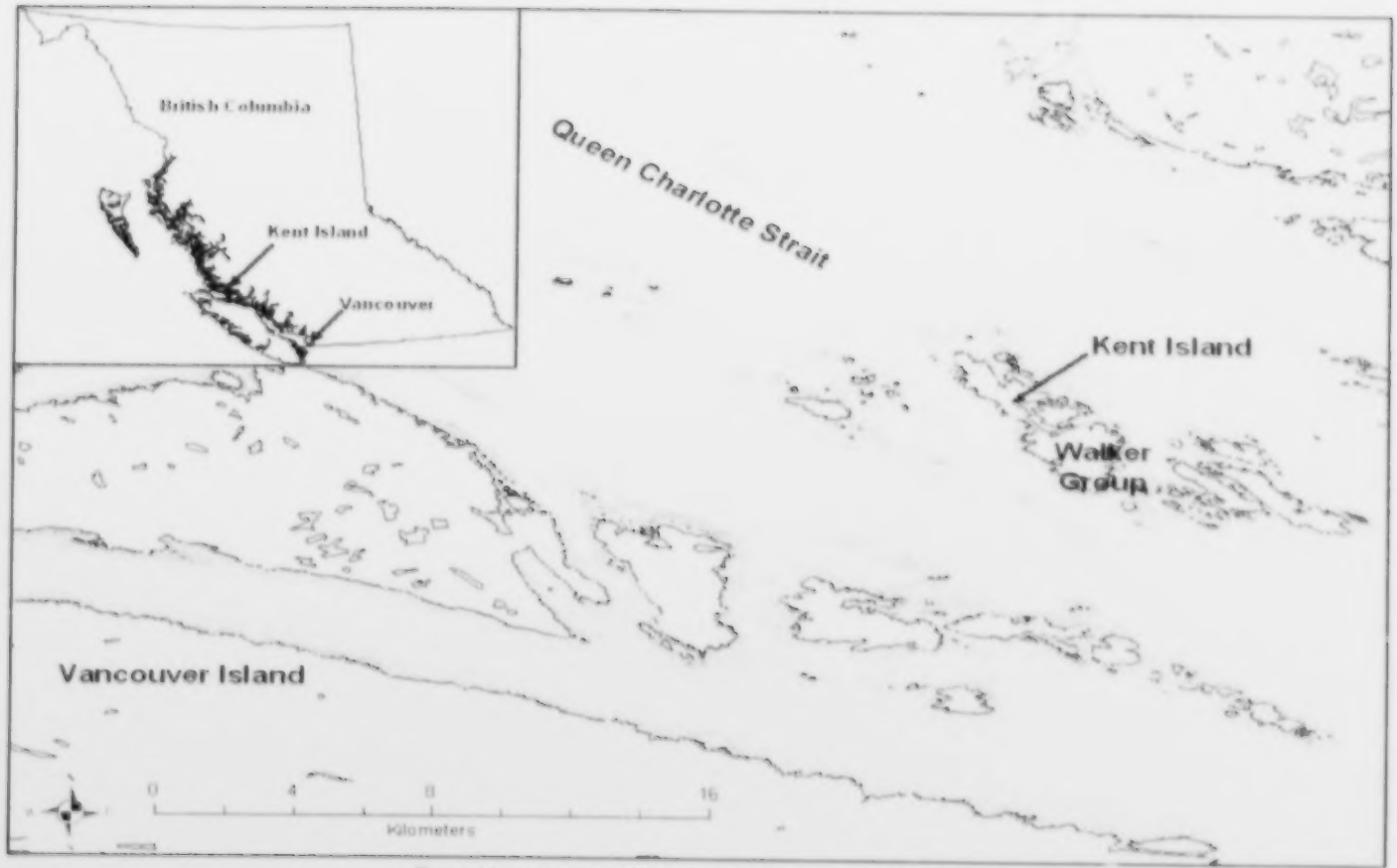


Figure 1 Location of Kent Island, British Columbia

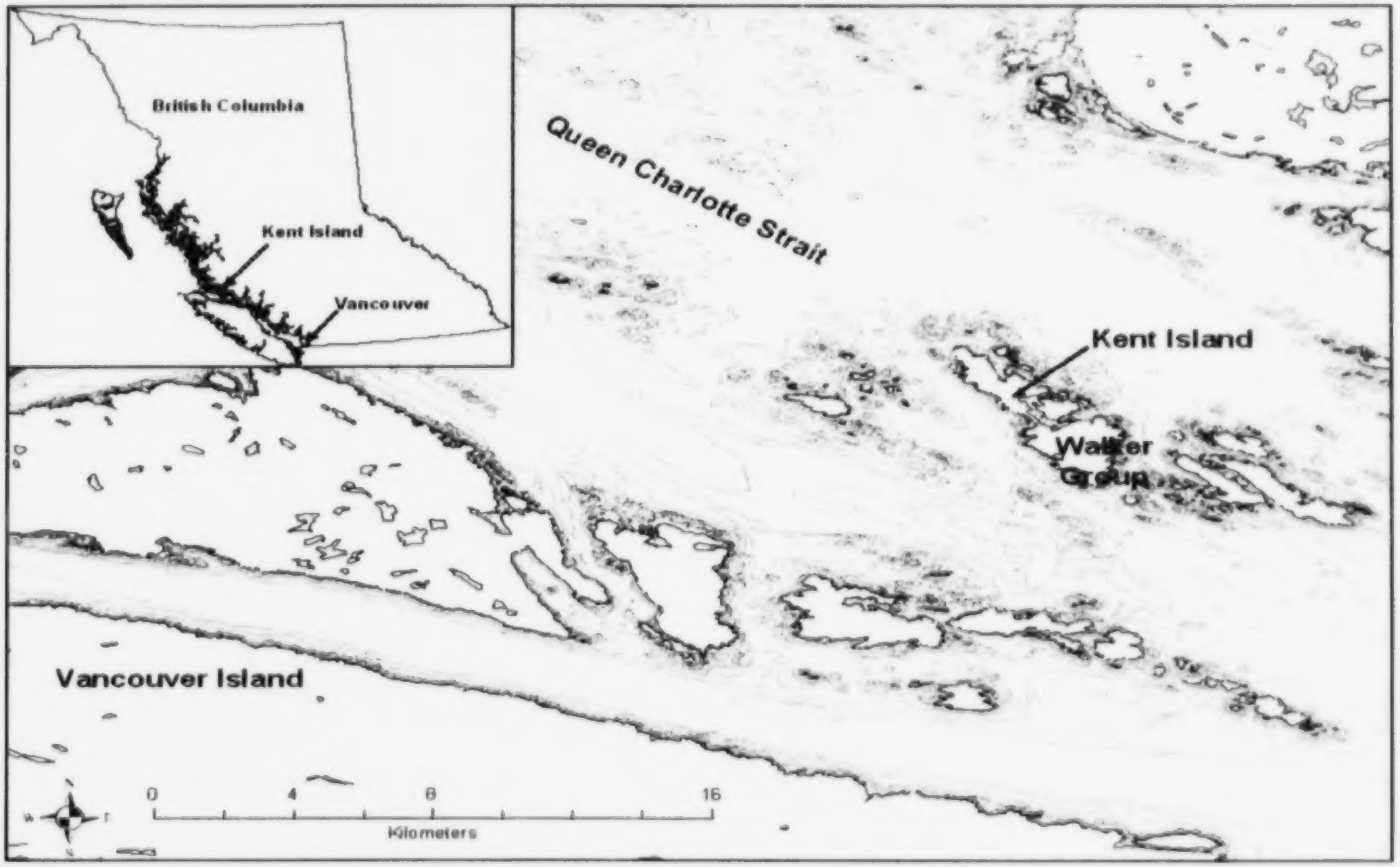


Figure 1 Location of Kent Island, British Columbia

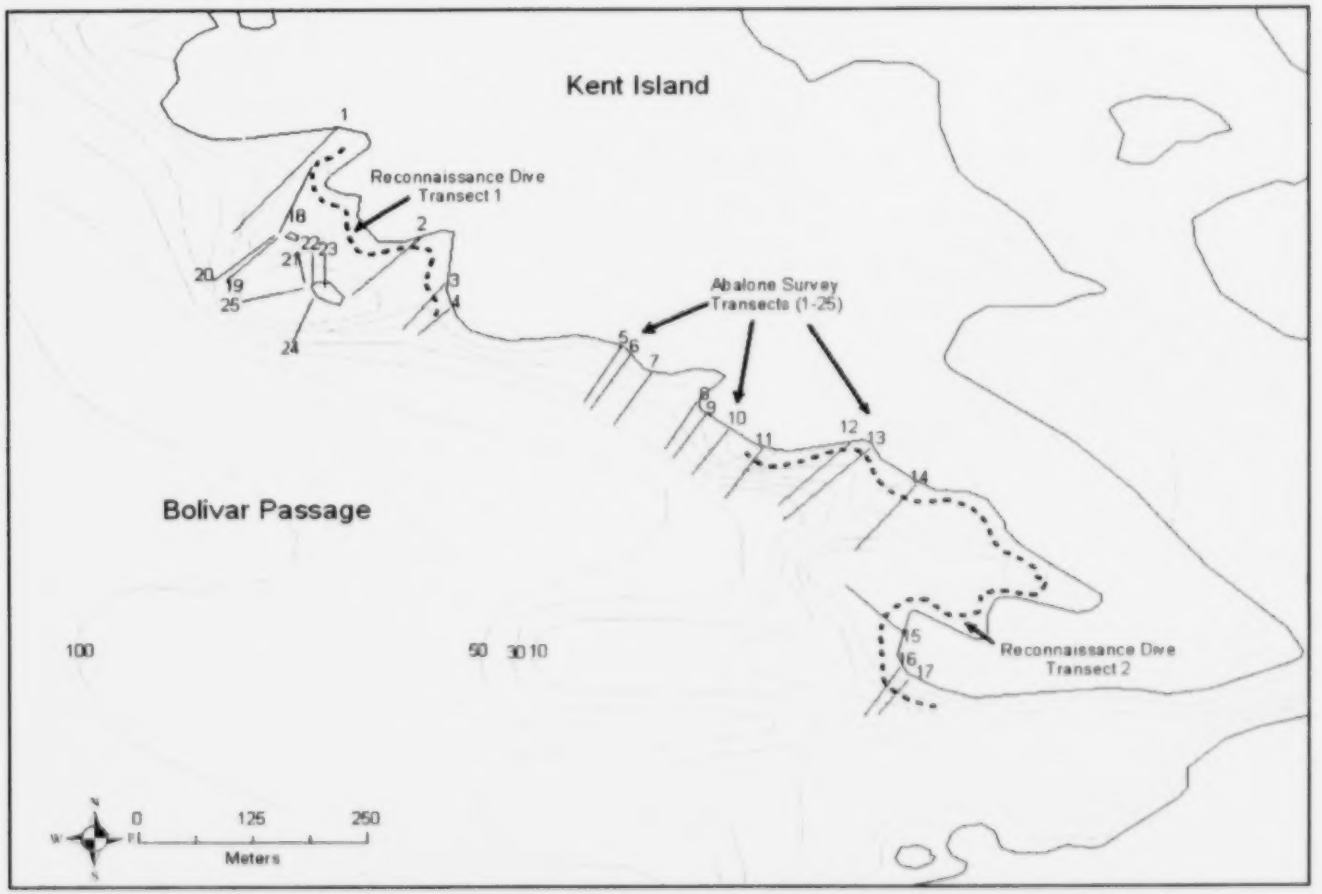


Figure 2. Location of shoreline reconnaissance dives and abalone transect dives at Kent Island, British Columbia

Table 1. Invertebrate species observed during a SCUBA survey at a fish farm at Kent Island, British Columbia on May 7, 2002.

| Common Name | Latin Name |
|---|---|
| California Sea Cucumber | *Parastichopus californicus* |
| Orange Sea Cucumber | *Cucumaria* sp. |
| California Mussel | *Mytilus californianus* |
| Green False-jingle | *Pododesmus macrochisma* |
| Rock Scallop | *Crassadoma gigantea* |
| Northern Abalone | *Haliotis kamtschatkana* |
| Rough Keyhole Limpet | *Diodora aspera* |
| Brown Turban Snail | *Tegula pulligo* |
| Topsnail | *Calliostoma* sp. |
| Whitecap Limpet | *Acmaea mitra* |
| Limpets | Various unidentified |
| Leafy Hornmouth | *Ceratastoma foliatum* |
| Oregon Triton | *Fusitriton oregonensis* |
| Giant Pacific Octopus | *Octopus dofleini* |
| Gumboot Chiton | *Cryptochiton stelleri* |
| Black Katy Chiton | *Katharina tunicata* |
| Lined Chiton | *Tonicella* sp. |
| Chitons | Various unidentified |
| Sunflower Star | *Pycnopodia helianthoides* |
| Painted Star | *Orthasterias koehleri* |
| Morning Star | *Solaster stimpsoni* |
| Leather Star | *Dermasterias imbricata* |
| Mottled Star | *Evasterias troschelii* |
| Blood Star | *Henricia leviuscula* |
| Ochre Star | *Pisaster ochraceus* |
| Brittle Star | *Ophiopholis aculeata* |
| Puget Sound King Crab | *Lopholithodes mandtii* |
| Decorator Crab | Unidentified |
| Kelp Crab | *Pugettia producta* |
| Hermit Crabs | Unidentified |
| Dock (Coonstripe) Shrimp | *Pandalus danae* |
| Shrimp | Unidentified |
| Red Sea Urchin | *Strongylocentrotus franciscanus* |
| Purple Sea Urchin | *Strongiyocentrotus purpuratus* |
| Green Sea Urchin | *Strongiyocentrotus droebachiensis* |
| Slime Tube Worm | *Myxicolla infundibulum* |
| Calcareous Tube Worms | *Serpula vermicularis* |
| Coralline Fringed Tube Worm | *Dodecaceria concharum* |
| Northern Feather Duster Worms | *Eudistylia vancouveri* |
| Double Crowned Feather Dusters | Unidentified |
| Brooding Anemone | *Epiactis prolifera* |
| Buried Anemone | *Urticina coriacea* |
| Giant Plumose Anemone | *Metridium giganteum* |
| Giant Green Anemone | *Anthopleura xanthogrammica* |
| Painted Anemone | *Urticina crassicornis* |
| White-spotted Anemone | *Urticina lofotensis* |
| Fish-Eating Anemone | *Urticina piscivora* |
| Tube-dwelling Anemone | *Pachycerianthus fimbriatus* |
| Anemones | Unidentified anemones |
| Pink Mouth Hydroid | *Ectopleura* sp. (probably other sp. as well) |
| Glassy Plume Hydroid | *Plumeria* sp. |
| Orange Cup Coral | *Balanophyllia elegans* |
| Tritonia | *Tritonia festiva* |
| Odhner's Dorid | *Archidoris odhneri* |
| Tochni | *Tochuina tetraquetra* |
| Opalescent Nudibranch | *Hermissenda crassicornis* |
| Unidentified Nudibranchs | Various sp. |
| Staghorn Bryozoan | *Heteropora magna* |
| Goose Barnacle | *Pollicipes polymerus* |
| Giant Barnacle | *Balanus nubilus* |
| Stalked Sea Squirt | *Styela montereyensis* |
| Glassy Sea Squirt | *Ascidia paratropa* |
| Colonial Purple Tunicate | Unidentified |
| Sea Squirts | Various unidentified |

Table 2. Flora and fish species observed during a SCUBA survey at a fish farm at Kent Island, British Columbia on May 7, 2002.

**Algae and Marine Plants**

| Common Name | Latin Name |
|---|---|
| Surf Grass | *Phyllospadix scouleri* |
| Fringed Sieve Kelp | *Agarum* sp. |
| Unidentified Red Filamentous Algae | Various sp. |
| Unidentified Brown Filamentous Algae | Various sp. |
| Iridescent Red | Various sp. |
| Encrusting Coralline Algae | Sp.? |
| Coralline Algae | Sp.? |
| Giant Kelp | *Macrocystis integrifolia* |
| Bull Kelp | *Nereocystis leutkeana* |
| Kelp | Laminarians |
| Split Kelp | *Laminaria groenlandica* |
| Sugar Kelp | *Laminaria saccharina* |
| Woody-stemmed Kelp | *Pterygophora californica* |
| Double Pom-pom Kelp | *Eisenia arborea* |
| Ribbon Kelp | *Alaria* sp. |
| Seersucker | *Costaria costata* |
| Acid Kelp | *Desmarestia* sp. |
| Three-ribbed Kelp | *Cymathere triplicata* |

**Fish**

| Common Name | Latin Name |
|---|---|
| Buffalo Sculpin | *Enophrys bison* |
| Kelp Greenling | *Hexagrammos decagrammus* |
| Painted Greenling | *Oxylebius pictus* |
| Yellowtail Rockfish | *Sebastes flavidus* |
| Black Rockfish | *Sebastes melanops* |
| Quillback Rockfish | *Sebastes maliger* |
| Copper Rockfish | *Sebastes caurinus* |
| Tube Snout | *Aulorhynchus flavidus* |
| Unidentified Sculpins | Various sp. |
| Black-eyed Goby | *Coryphopterus nicholsi* |
| Goby | Unidentified |

Table 3. Abalone observed during a SCUBA dive at a fish farm at Kent Island, British Columbia.

| Transect | Transect Length (m) | Number of Quadrats | Number of Abalone |
|---|---|---|---|
| 1 | 18 | 9 | 2 |
| 2 | 28 | 14 | 2 |
| 3 | 12 | 6 | 0 |
| 4 | 14 | 7 | 4 |
| 5 | 18 | 9 | 2 |
| 6 | 12 | 6 | 0 |
| 7 | 12 | 6 | 0 |
| 8 | 22 | 11 | 0 |
| 9 | 18 | 9 | 0 |
| 10 | 18 | 9 | 3 |
| 11 | 16 | 8 | 2 |
| 12 | 28 | 14 | 0 |
| 13 | 18 | 9 | 0 |
| 14 | 30 | 15 | 0 |
| 15 | 30 | 15 | 2 |
| 16 | 18 | 9 | 3 |
| 17 | 16 | 8 | 1 |
| 18 | 18 | 9 | 1 |
| 19 | 30 | 15 | 1 |
| 20 | 24 | 12 | 1 |
| 21 | 34 | 17 | 6 |
| 22 | 16 | 8 | 1 |
| 23 | 14 | 7 | 2 |
| 24 | 26 | 13 | 0 |
| 25 | 40 | 20 | 1 |

Table 4. GPS coordinates of the corners of the netpen structure at Kent Island, British Columbia (NP = netpen).

| Corner | GPS coordinates | Date | Vessel |
|---|---|---|---|
| NP-1 | N 50° 53.925'<br>W 127° 32.438' | June 4, 2002 | Port Hardy 1 |
| NP-2 | N 50° 53.942'<br>W 127° 32.298' | June 4, 2002 | Port Hardy 1 |
| NP-3 | N 50° 53.977'<br>W 127° 32.310' | June 5, 2002 | Chimaera IV |
| NP-4 | N 50° 53.960'<br>W 127° 32.454' | June 5, 2002 | Chimaera IV |

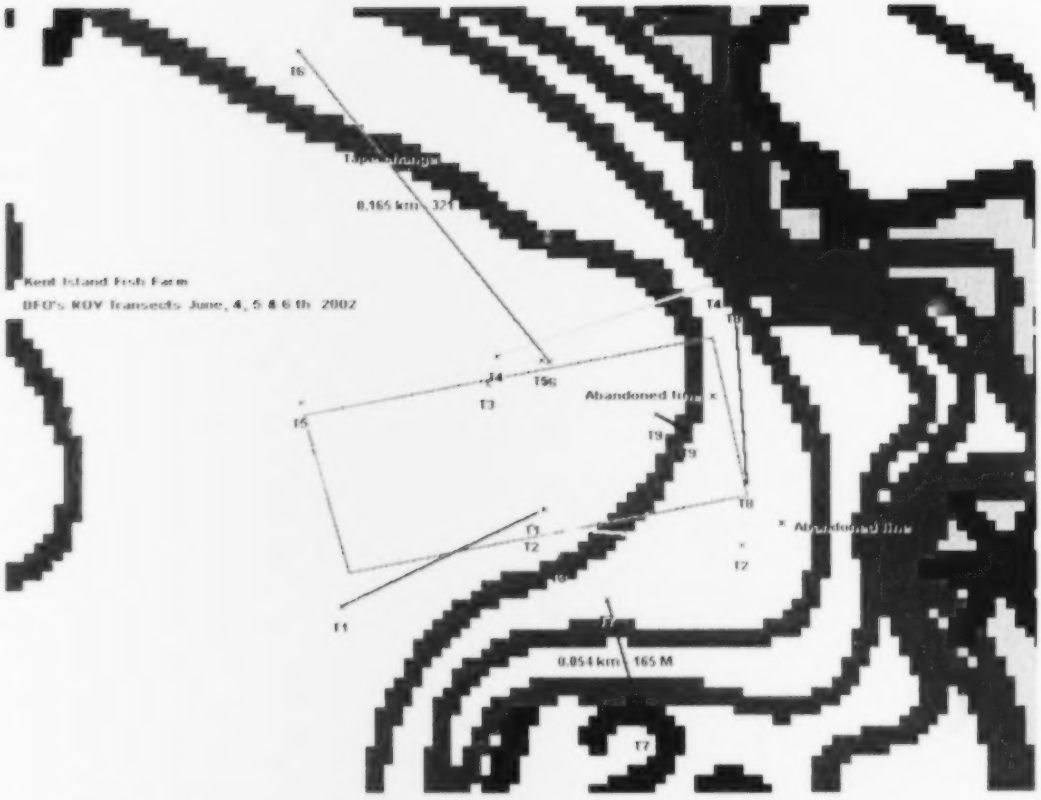


Figure 3. Location of ROV survey transects at Kent Island, British Columbia.

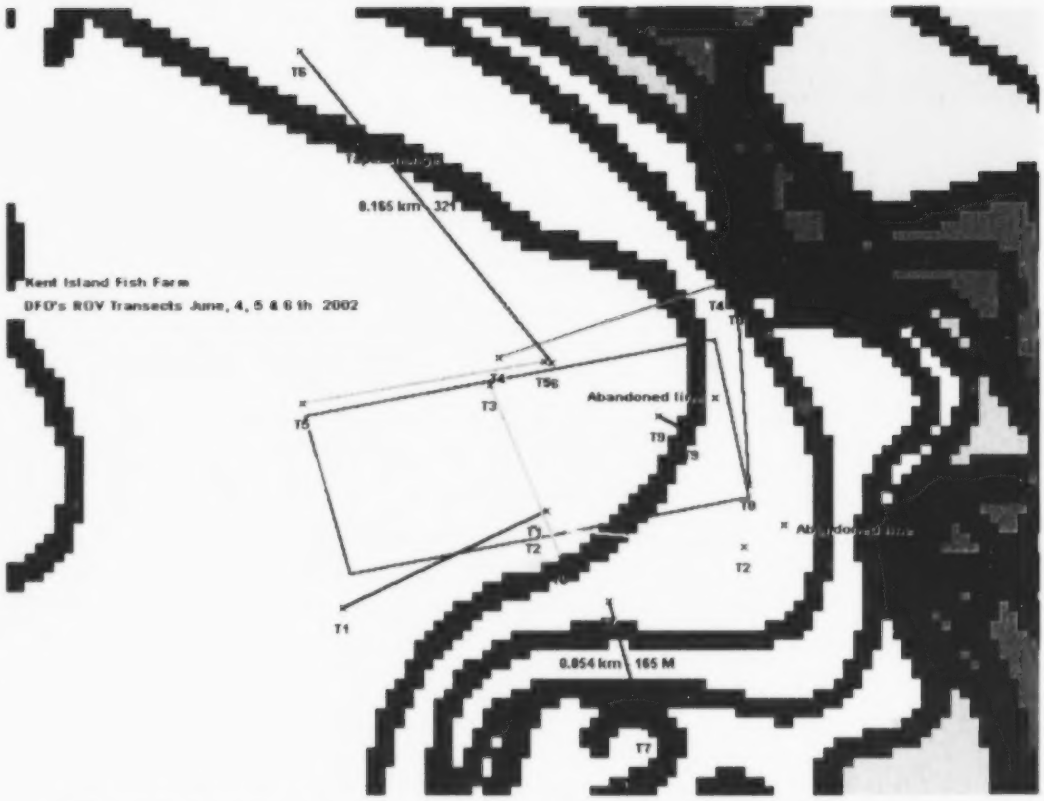


Figure 3. Location of ROV survey transects at Kent Island, British Columbia.

Table 5. Invertebrate, fish and algae species observed during ROV survey at Kent Island, British Columbia.

| Common Name | Latin Name |
|---|---|
| **Invertebrates** | |
| California Sea Cucumber | *Parastichopus californicus* |
| Unidentified White Cucumber on sand | Possibly *Pentamara* sp. |
| Pedal Cucumber | *Psolus chitonoides* |
| Swimming Scallop | *Chlamys* sp. |
| Oregon Triton | *Fusitriton oregonensis* |
| Red Flabellina Nudibranch | *Flabellina triophina* |
| Red Octopus | *Octopus rubenscens* |
| Pink Pisaster | *Pisaster brevispinus* |
| Painted Star | *Orthasterias koehleri* |
| Striped Sunstar | *Solaster stimpsoni* |
| Morning Sunstar | *Solaster dawsoni* |
| Blood Star | *Henricia leviuscula* |
| Vermillion Star | *Mediaster aequalis* |
| Rose Star | *Crossaster papposus* |
| Wrinkled Star | *Pteraster militaris* |
| Brittle Star | Unidentified |
| Sun Star | *Solaster* sp. |
| Red Sea Urchin | *Strongylocentrotus franciscanus* |
| Calcareous Tube Worms | *Serpula* sp. |
| Unidentified Sediment Tube Worms | |
| Snakelock Anemone | *Cribrinopsis fernaldi* |
| Giant Plumose Anemone | *Metridium giganteum* |
| Sea Pen | *Ptilosarcus gurneyi* |
| Orange Cup Coral | *Balanophyllia elegans* |
| Staghorn Bryozoan | *Heteropora magna* |
| Unidentified Hydrozoans/Bryozoans | |
| Sea Peach | *Halocynthia aurantium* |
| Sea Squirts | Various unidentified |
| Hexactinellid sponge | |
| Yellow Boring Sponge | *Cliona celata* |
| Rough Scallop Sponge | *Myxilla incrustans* |
| Unidentified White Finger-like Sponge | |
| Unidentified Stalked Trumpet-like Sponge | Possibly *Stylissa* |
| Sea Spider | *Pycnogonida* |
| **Fish** | |
| Kelp Greenling | *Hexagrammos decagrammus* |
| Cod | *Gadidiae* |
| Yellowtail Rockfish | *Sebastes flavidus* |
| Quillback Rockfish | *Sebastes maliger* |
| Tiger Rockfish | *Sebastes nigrocinctus* |
| Rat Fish | *Hydrolagus colliei* |
| Rock Sole | *Lepidopsetta bilineata* |
| Unidentified Rockfish | Most likely Sharpchin |
| **Algae** | |
| Encrusting Coralline Algae | Unidentified |

Table 6. Description of grab sampling information at both farm (S, KI) and reference (RF) stations, Kent Island, British Columbia.

| Station | Date | GPS Location | Grab Type | Depth (m) | Time (PDT) | General Observations |
|---|---|---|---|---|---|---|
| S-9 | Sept 13, 2002 | N 50° 53.933' W 127° 32.447' | Ponar | 71 | 13:51 | Light odour, small sample, some dark surface area, red worms |
| S-10 | Sept 13, 2002 | N 50° 53.950' W 127° 32.451' | Ponar | 84 | 12:06 | Moderate odour, black surface layer, red worms, small sample |
| S-17 | Sept 12, 2002 | N 50° 53.953' W 127° 32.376' | Ponar | 84 | 9:21 | Strong odour, black surface layer, red worms |
| KI-1 | Oct 1, 2002 | N 50° 53.975' W 127° 32.317' | Van Veen | 65 | 8:49 | Shell hash, moderate odour, brown colour, gas bubbles |
| KI-3 | Oct 1, 2002 | N 50° 53.943' W 127° 32.306' | Van Veen | 39 | 13:10 | No odour, worm tubes |
| KI-5 | Oct 1, 2002 | N 50° 53.935' W 127° 32.381' | Van Veen | 71 | 12:26 | Strong odour, black colour, gritty texture, dead clams |
| KI-6 | Oct 1, 2002 | N 50° 53.931' W 127° 32.405' | Van Veen | 77 | 12:05 | Strong odour, black surface, gritty texture, dead clams |
| KI-7 | Oct 1, 2002 | N 50° 53.928' W 127° 32.433' | Van Veen | 75 | 11:49 | Moderate odour |
| KI-8 | Oct 1, 2002 | N 50° 53.936' W 127° 32.443' | Van Veen | 85 | 11:05 | N/A |
| KI-9 | Oct 1, 2002 | N 50° 53.959' W 127° 32.442' | Van Veen | 87 | 10:41 | N/A |
| KI-10 | Oct 1, 2002 | N 50° 53.963' W 127° 32.414' | Van Veen | 79 | 10:12 | N/A |
| KI-11 | Oct 1, 2002 | N 50° 53.968' W 127° 32.376' | Van Veen | 72 | 9:42 | Rocks, little shell hash, small crab |
| KI-12 | Oct 1, 2002 | N 50° 53.971' W 127° 32.344' | Van Veen | 67 | 9:15 | Brown colour, moderate odour, shell hash, worm tubes |
| RF-1 | Oct 1, 2002 | N 50° 54.123' W 127° 30.973' | Van Veen | 68 | 14:43 | Brown colour, no odour |
| RF-2 | Oct 1, 2002 | N 50° 54.144' W 127° 30.914' | Van Veen | 69 | 15:12 | Brown colour, no odour |
| RF-3 | Oct 1, 2002 | N 50° 54.092' W 127° 30.958' | Van Veen | 60 | 15:26 | Brown colour, no odour |

Table 7. Sediment grain size fractions (Ocean Dumping and Ocean Dumping Extra Points Protocols) of grab samples collected at Kent Island, British Columbia.

| | Sampling Station | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ocean Dumping Protocol | S-9 | S-10 | S-17 | KI-1 | KI-3 | KI-6 | KI-7 | KI-8 | KI-9 | KI-10 | KI-11 | KI-12 | RF-1 | RF-2 | RF-3 |
| Gravel, >2 mm | 0.82 | 2.12 | 3.34 | 17.77 | 2.91 | 9.00 | 45.68 | 0.70 | 0.35 | 0.94 | 12.04 | 18.28 | 9.27 | 0.37 | 0.27 |
| Sand, <2.00 mm >0.063 mm | 87.92 | 86.93 | 79.26 | 48.00 | 76.12 | 76.06 | 48.47 | 90.05 | 91.01 | 89.92 | 70.91 | 47.59 | 61.93 | 93.92 | 93.32 |
| Silt, <0.063 mm >0.004 mm | 5.49 | 4.78 | 7.39 | 13.43 | 7.22 | 6.01 | 2.41 | 3.68 | 3.42 | 3.75 | 6.48 | 13.20 | 10.53 | 1.87 | 2.28 |
| Clay, <0.004 mm | 5.77 | 6.17 | 10.01 | 20.80 | 13.75 | 8.93 | 3.44 | 5.57 | 5.23 | 5.50 | 10.56 | 20.94 | 18.28 | 3.85 | 4.13 |

| | Sampling Station | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ocean Dumping Extra Points Protocol | S-9 | S-10 | S-17 | KI-1 | KI-3 | KI-6 | KI-7 | KI-8 | KI-9 | KI-10 | KI-11 | KI-12 | RF-1 | RF-2 | RF-3 |
| Gravel, >2 mm | 0.82 | 2.12 | 3.34 | 17.77 | 2.91 | 9.00 | 45.68 | 0.70 | 0.35 | 0.94 | 12.04 | 18.28 | 9.27 | 0.37 | 0.27 |
| <2.00 mm | 0.10 | 0.06 | 0.41 | 5.58 | 1.41 | 1.18 | 4.23 | 0.08 | 0.10 | 0.05 | 0.52 | 2.85 | 1.63 | 0.04 | 0.01 |
| <1.00 mm | 0.23 | 0.11 | 0.68 | 3.75 | 2.15 | 1.89 | 0.26 | 0.21 | 0.15 | 0.15 | 0.68 | 2.44 | 1.49 | 0.06 | 0.07 |
| <0.500 mm, | 2.42 | 1.36 | 3.50 | 4.31 | 8.12 | 6.79 | 3.87 | 2.79 | 1.74 | 1.84 | 3.06 | 3.56 | 2.72 | 0.69 | 1.03 |
| <0.250 mm | 48.13 | 43.42 | 40.51 | 12.37 | 38.07 | 38.71 | 27.30 | 51.08 | 48.49 | 48.90 | 34.28 | 15.71 | 18.50 | 48.06 | 44.71 |
| <0.125 mm | 37.04 | 41.98 | 34.16 | 21.99 | 26.37 | 27.49 | 17.05 | 35.89 | 40.52 | 38.87 | 32.37 | 23.03 | 37.59 | 45.07 | 47.49 |
| <0.063 mm | 5.49 | 4.78 | 7.39 | 13.43 | 7.22 | 6.01 | 2.40 | 3.68 | 3.42 | 3.75 | 6.49 | 13.19 | 10.52 | 1.86 | 2.29 |
| <0.004 mm | 0.97 | 1.05 | 1.93 | 3.89 | 2.78 | 2.04 | 0.71 | 0.91 | 0.80 | 0.87 | 2.12 | 3.85 | 3.09 | 0.45 | 0.55 |
| <0.002 mm | 4.80 | 5.12 | 8.08 | 16.91 | 10.97 | 6.89 | 2.73 | 4.66 | 4.43 | 4.63 | 8.44 | 17.09 | 15.19 | 3.40 | 3.58 |

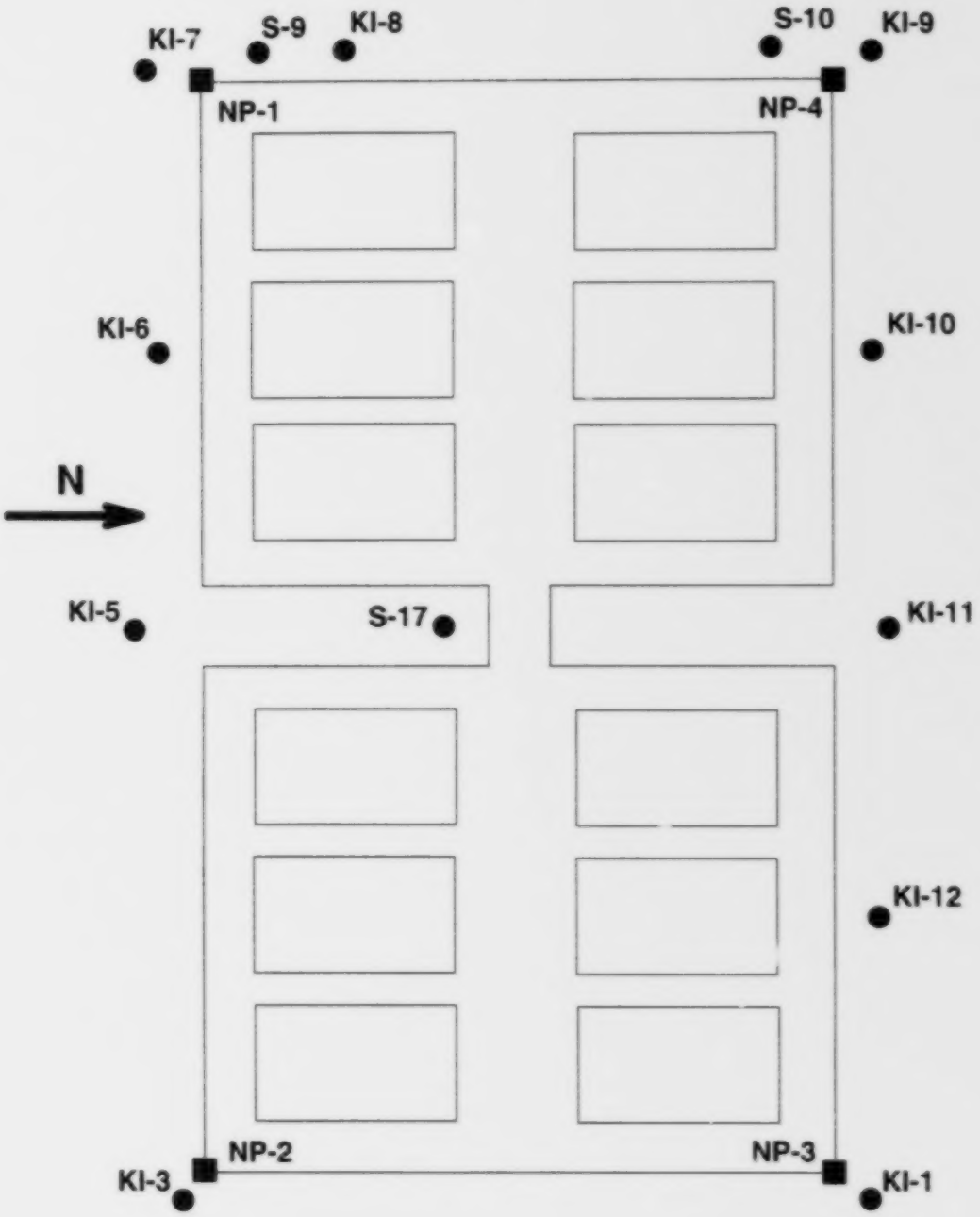


Figure 5. Approximate locations of grab sampling stations relative to the netpen layout at Kent Island, British Columbia.

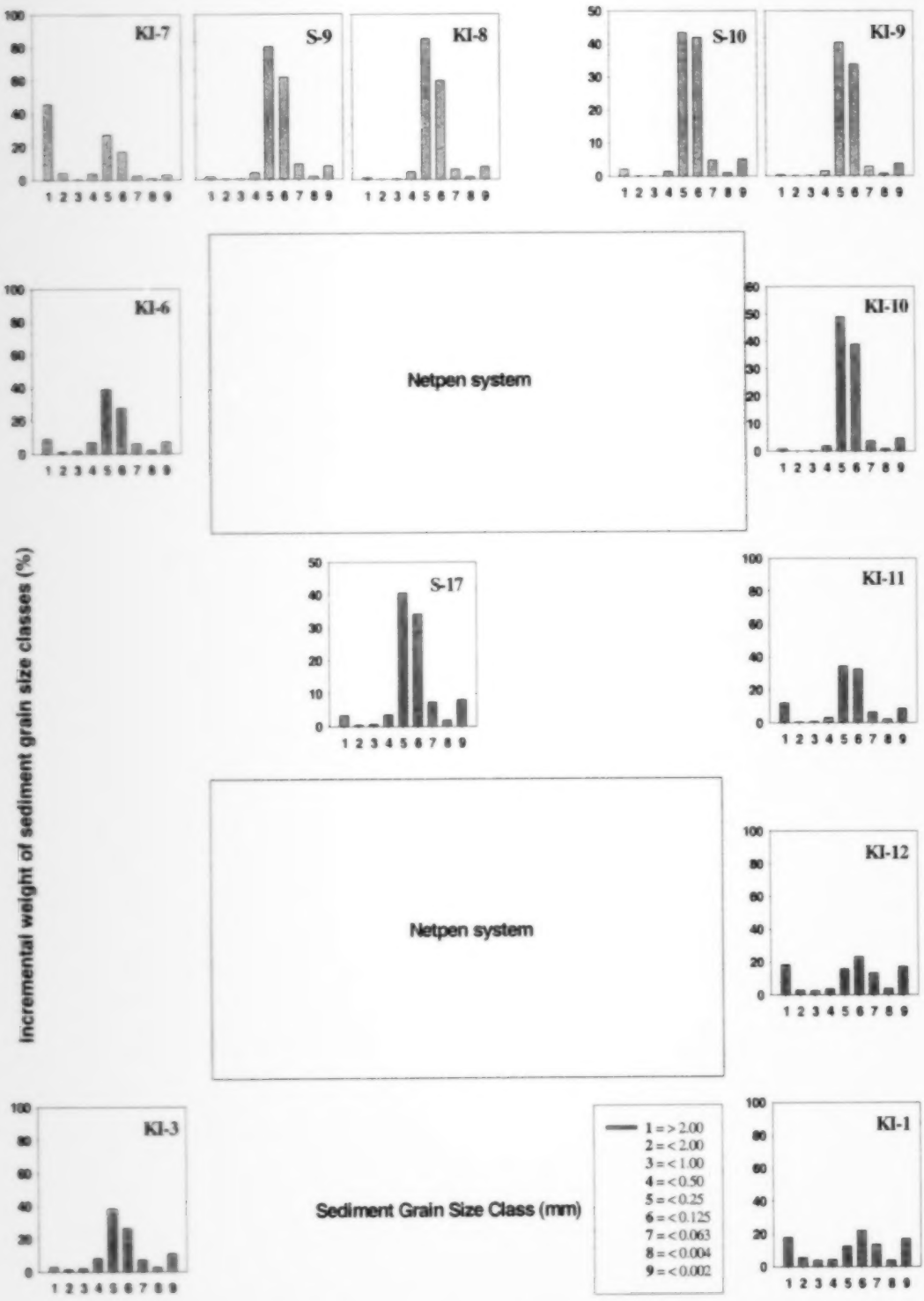


Figure 6. Sediment grain size fractions observed at farm sampling stations at Kent Island, British Columbia.

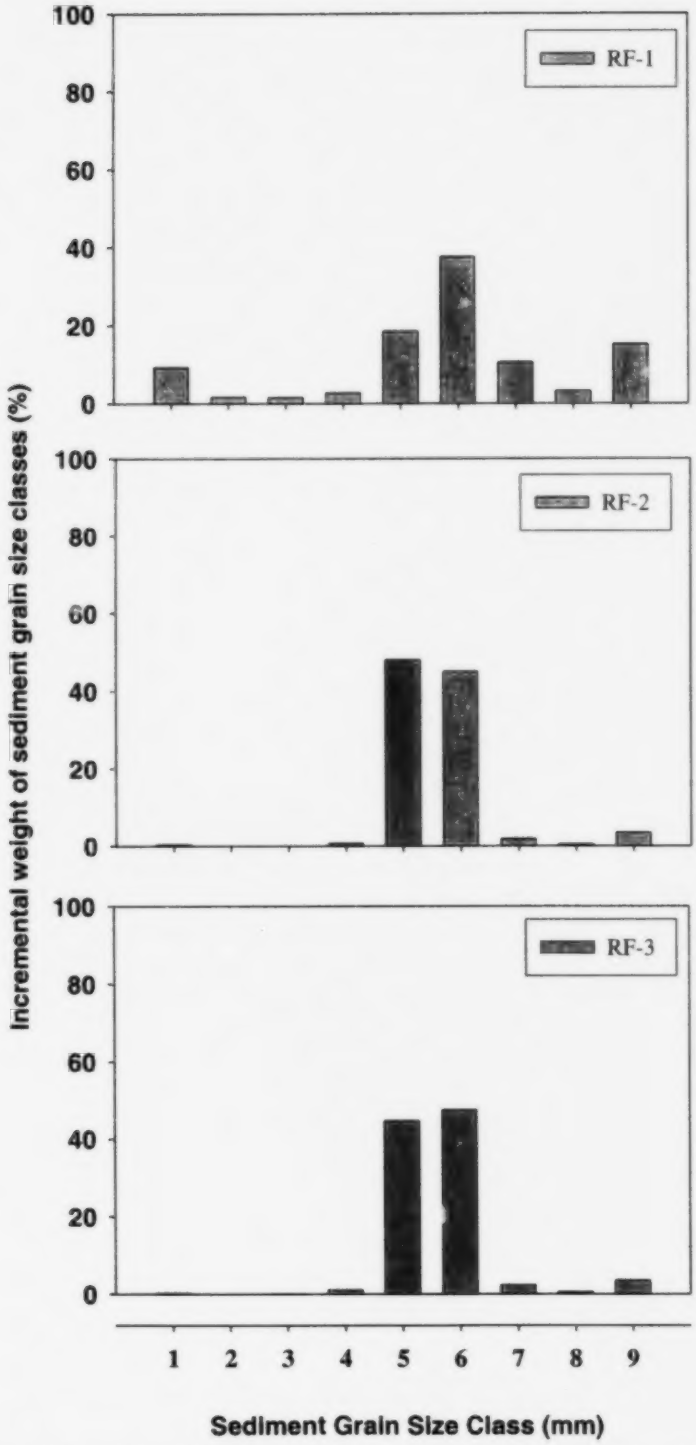


Figure 7. Sediment grain size fractions observed at reference stations at Kent Island, British Columbia.

Table 8. Sediment total carbon and total nitrogen contents observed at farm and reference stations at Kent Island, British Columbia.

| Sampling Station | Percent Total Carbon | Total Nitrogen |
|---|---|---|
| | (%) | ($\mu g\ g^{-1}$) |
| S-9 | 2.04 | 761 |
| S-10 | 1.90 | 637 |
| S-17 | 4.09 | 1273 |
| KI-1 | 7.93 | 2360 |
| KI-3 | 4.26 | 1772 |
| KI-5 | 5.12 | 1552 |
| KI-6 | 4.19 | 1895 |
| KI-7 | 3.25 | 776 |
| KI-8 | 1.92 | 689 |
| KI-9 | 2.43 | 758 |
| KI-10 | 1.83 | 876 |
| KI-11 | 4.26 | 1222 |
| KI-12 | 7.96 | 2254 |
| RF-1 | 3.05 | 1636 |
| RF-2 | 0.68 | 641 |
| RF-3 | 0.55 | 590 |

Table 9. Sediment trace-metal concentrations observed at farm and reference stations at Kent Island, British Columbia.

| Element | Stations Sampled | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S-9 | S-10 | S-17 | KI-1 | KI-3 | KI-5 | KI-6 | KI-7 | KI-8 | KI-9 | KI-10 | KI-11 | KI-12 | RF-1 | RF-2 | RF-3 |
| | ($\mu g\ g^{-1}$) | | | | | | | | | | | | | | | |
| Aluminum | 16667 | 16425 | 18626 | 20593 | 16442 | 18208 | 14826 | 15780 | 14573 | 14600 | 12470 | 16711 | 17852 | 13757 | 11062 | 12619 |
| Antimony | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Arsenic | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Barium | 26.7 | 29.0 | 30.4 | 61.6 | 35.7 | 37.9 | 25.9 | 22.6 | 22.2 | 21.3 | 18.5 | 32.6 | 48.9 | 33.6 | 17.8 | 20.6 |
| Beryllium | 0.4 | 0.5 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.5 | 0.5 | 0.5 |
| Boron | 0 | 0 | 0 | 10 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 7 | 0 | 0 |
| Cadmium | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Calcium | 35262 | 25271 | 41782 | 80506 | 52301 | 49968 | 44621 | 30059 | 27811 | 27176 | 24641 | 33600 | 68427 | 35008 | 13918 | 15245 |
| Chromium | 19.0 | 18.9 | 22.0 | 24.0 | 18.8 | 21.0 | 18.3 | 19.2 | 18.3 | 18.7 | 15.9 | 19.7 | 22.5 | 16.8 | 14.0 | 14.6 |
| Cobalt | 8.4 | 8.5 | 9.1 | 7.9 | 7.5 | 7.9 | 7.3 | 8.5 | 8.4 | 8.3 | 7.8 | 8.4 | 7.8 | 6.9 | 6.8 | 7.3 |
| Copper | 11.3 | 13.7 | 14.4 | 13.8 | 18.5 | 12.0 | 11.7 | 11.2 | 10.6 | 10.4 | 10.7 | 12.9 | 15.9 | 10.6 | 8.2 | 8.3 |
| Iron | 19687 | 19551 | 23247 | 21076 | 18149 | 20736 | 18811 | 20789 | 19059 | 19127 | 16608 | 19665 | 20111 | 15586 | 13770 | 14988.0 |
| Lead | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Magnesium | 6237 | 5928 | 7292 | 9666 | 7555 | 7479 | 6808 | 6261 | 5978 | 5872 | 5467 | 6515 | 8068 | 6028 | 4541 | 4855 |
| Manganese | 274.6 | 279.1 | 300.6 | 257.7 | 221.2 | 271.8 | 218.5 | 260.1 | 245.5 | 246.6 | 215.5 | 264.0 | 244.2 | 211.2 | 191.8 | 218.2 |
| Molybdenum | 0 | 0 | 3 | 0 | 2 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nickel | 13 | 12 | 13 | 18 | 13 | 13 | 12 | 12 | 12 | 13 | 12 | 14 | 16 | 12 | 10 | 10 |
| Phosphorus | 720 | 701 | 1848 | 1106 | 1365 | 1518 | 2913 | 1052 | 746 | 1461 | 834 | 874 | 959 | 640 | 576 | 590 |
| Potassium | 1489 | 1419 | 1793 | 3455 | 2134 | 2246 | 1703 | 1329 | 1299 | 1264 | 1086 | 1769 | 2656 | 1869 | 1053 | 1176 |
| Selenium | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Silicon | 609 | 656 | 478 | 661 | 469 | 541 | 633 | 672 | 702 | 865 | 631 | 897 | 620 | 771 | 1760 | 756 |
| Silver | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sodium | 5038 | 3937 | 6483 | 17569 | 10246 | 8768 | 8465 | 4933 | 5432 | 5122 | 4497 | 5502 | 8956 | 7811 | 4734 | 4606 |
| Strontium | 236.5 | 164.4 | 317.1 | 852.8 | 469.0 | 441.7 | 343.0 | 204.5 | 178.3 | 169.6 | 148.6 | 241.5 | 609.9 | 285.2 | 86.3 | 97.6 |
| Sulfur | 1306 | 1203 | 2196 | 3677 | 2429 | 2706 | 2765 | 1560 | 1332 | 1410 | 1303 | 1628 | 2992 | 1904 | 1080 | 1112 |
| Tin | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 |
| Titanium | 2293.6 | 2313.7 | 2439.4 | 1891.3 | 1775.5 | 1993.8 | 1758.8 | 2286.3 | 2224.7 | 2197.9 | 1970.5 | 2173.2 | 1898.8 | 1764.6 | 1803.5 | 1999.0 |
| Vanadium | 77 | 77 | 92 | 75 | 65 | 76 | 69 | 82 | 76 | 77 | 66 | 79 | 75 | 59 | 54 | 60 |
| Zinc | 35.4 | 34.0 | 50.0 | 58.4 | 49.2 | 52.5 | 53.2 | 37.1 | 35.2 | 36.2 | 34.4 | 41.3 | 52.9 | 37.7 | 25.7 | 27.5 |

Table 10. Detection limits for sediment trace-metal analysis conducted on an Optima 4300 inductively coupled plasma emission spectrometer. (PESC. SEDMET Method V 6.0).

| Element | Detection Limit ($\mu g\ g^{-1}$) |
|---|---|
| **(ICP Total)** | |
| Aluminum | 8 |
| Antimony | 8 |
| Arsenic | 8 |
| Barium | 0.2 |
| Beryllium | 0.2 |
| Boron | 2 |
| Cadmium | 0.8 |
| Calcium | 20 |
| Chromium | 0.8 |
| Cobalt | 0.8 |
| Copper | 0.8 |
| Iron | 0.8 |
| Lead | 8 |
| Magnesium | 20 |
| Manganese | 0.2 |
| Molybdenum | 2 |
| Nickel | 3 |
| Phosphorus | 20 |
| Potassium | 20 |
| Selenium | 8 |
| Silicon | 8 |
| Silver | 2 |
| Sodium | 20 |
| Strontium | 0.2 |
| Sulfur | 8 |
| Tin | 8 |
| Titanium | 0.3 |
| Vanadium | 2 |
| Zinc | 0.3 |

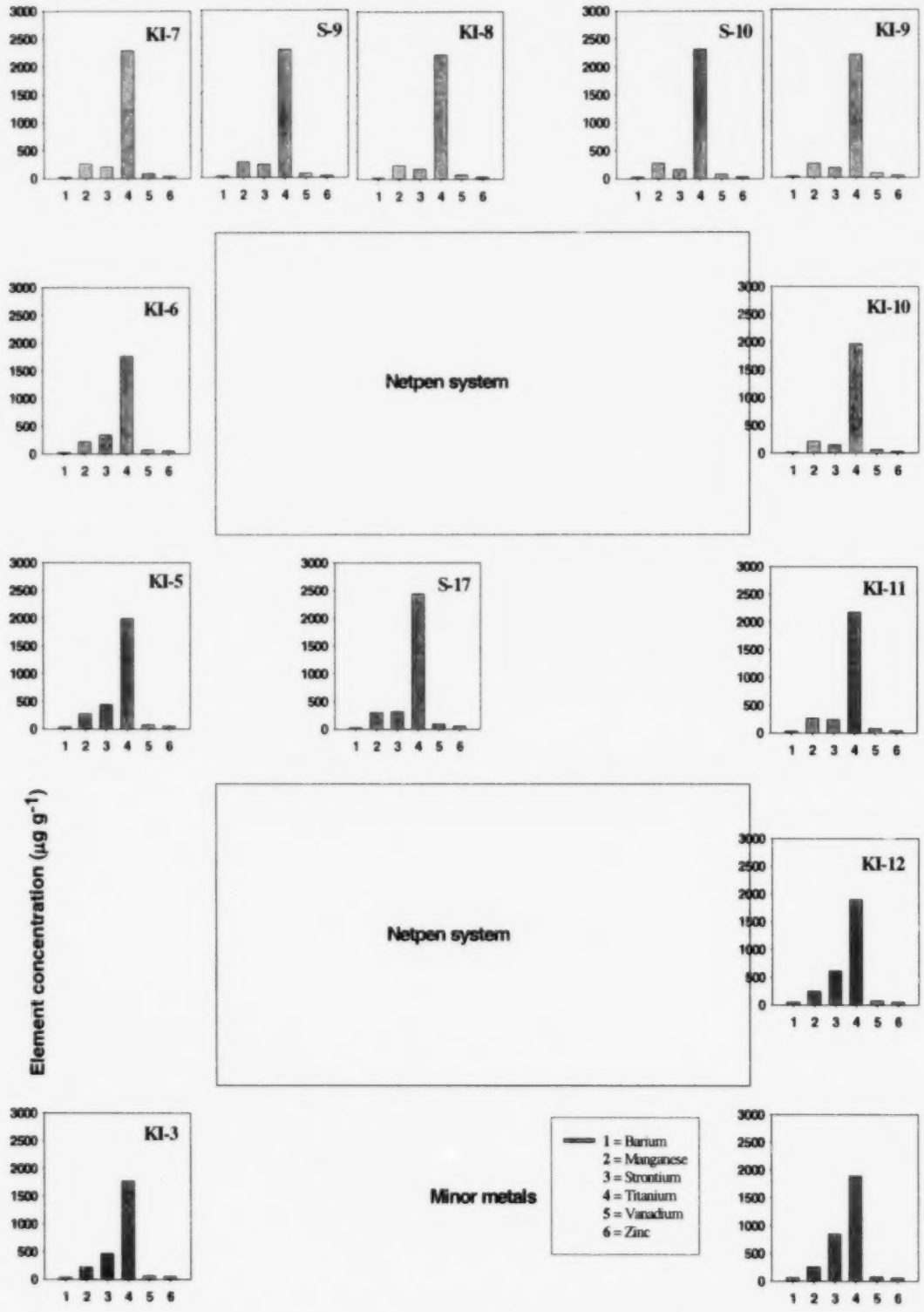


Figure 8. Sediment minor metals observed at farm sampling stations at Kent Island, Britsh Columbia.

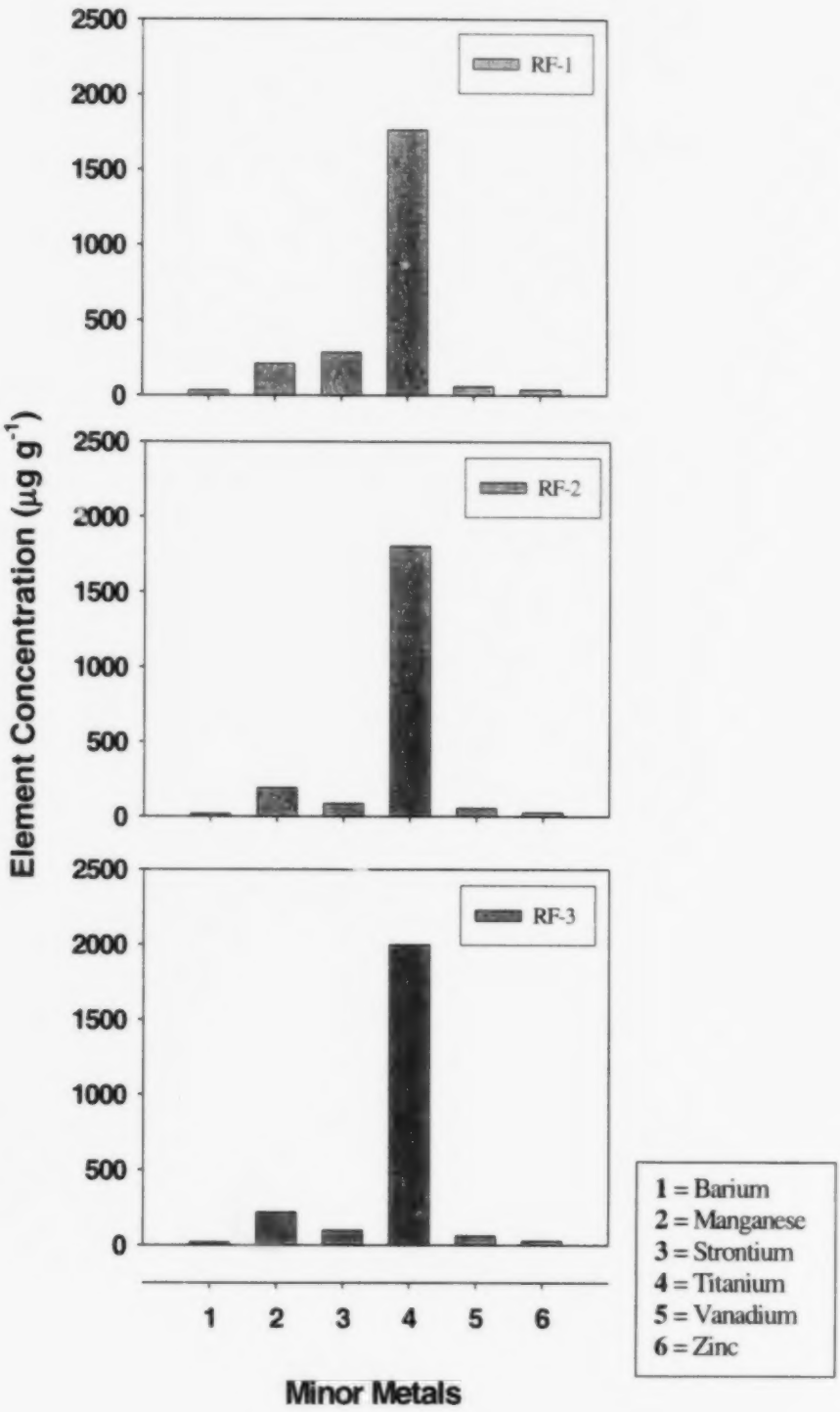


Figure 9. Sediment minor metals observed at reference stations at Kent Island, British Columbia.

Table 11. Benthic debris descriptions observed at farm and reference sampling stations at Kent Island, British Columbia.

| Station | Benthic Debris Description |
|---|---|
| S-9 | Worm tube fragments, woody debris (to 9.0 cm), shell fragments (to 4.5 cm), organic debris, urchin spine fragments, foraminiferan tests, and gravel (to 2.5 cm). 150 mL |
| S-10 | Worm tube fragments, woody debris (to 1.5 cm; <5% charcoal), organic debris, shell fragments (to 3.0 cm), foraminiferan tests, and algae. 100 mL |
| S-17 | Worm tube fragments, shell fragments (to 3.0 cm), organic debris, woody debris (to 3.5 cm; <5% charcoal), and urchin spine fragments. 400 mL |
| KI-1 | Shell fragments (to 4.5 cm), organic debris, wood fragments (to 3.0 cm), urchin spine fragments, sand, foraminiferan tests, and gravel (to 2.0 cm). 1450 mL |
| KI-3 | Shell fragments (to 6.5 cm), worm tube fragments (including *Phyllochaetopterus* tubes), sand, foraminiferan tests, bryozoan tests, urchin spine fragments, organic debris, woody debris (to 4.0 cm), and algae. 1450 mL |
| KI-5 | Shell fragments (to 2.5 cm), worm tube fragments, foraminiferan tests, sand, organic debris, woody debris (to 2.0 cm), urchin spine fragments, bryozoan tests, algae, and gravel (to 1.0 cm). 1300 mL |
| KI-6 | Shell fragments (to 3.0 cm), worm tube fragments, woody debris (to 3.0 cm; <25% charcoal), organic debris, foraminiferan tests, gravel (to 2.0 cm), sand, and algae. 900 mL |
| KI-7 | Shell fragments (to 2.5 cm), organic debris, worm tube fragments, woody debris (to 2.5 cm; 10% charcoal), foraminiferan tests, sand, and algae. 550 mL |
| KI-8 | Organic debris, woody debris (to 1.5 cm; <5% charcoal), worm tube fragments, and shell fragments (to 3.5 cm). 350 mL |
| KI-9 | Organic debris, worm tube fragments, woody debris (to 2.5 cm; <5% charcoal), and shell debris (to 4.0 cm). 400 mL |
| KI-10 | Worm tube fragments, shell fragments (to 4.0 cm), wood fragments (to 2.0 cm; <5% charcoal), organic debris, foraminiferan tests, and urchin spine fragments. 400 mL |
| KI-11 | Shell fragments (to 2.5 cm), worm tube fragments, woody debris (to 5.5 cm; <5% charcoal), organic debris, urchin spine fragments, gravel (to 2.5 cm), and algae. 550 mL |
| KI-12 | Shell fragments (to 4.0 cm), organic debris, woody debris (to 2.5 cm; 5% charcoal), foraminiferan tests, urchin spine fragments, worm tube fragments, bryozoan tests, sand, and gravel (to 2.0 cm). 1650 mL |
| RF-1 | Shell fragments (to 4.5 cm), worm tube fragments, organic debris, woody debris (to 1.5 cm), bryozoan tests, urchin spine fragments, sand, foraminiferan tests, and gravel (to 1.5 cm). 750 mL |
| RF-2 | Worm tube fragments, shell fragments (to 5.0 cm), woody debris (to 2.0 cm; <5% charcoal), organic debris, and foraminiferan tests. 100 mL |
| RF-3 | Worm tube fragments, shell fragments (to 4.5 cm), woody fragments (to 2.0 cm; <5% charcoal), and ophiuroid fragments. 100 mL |

Table 12. Macrofaunal abundance observed at farm and reference stations at Kent Island, British Columbia.

| Taxon | Sampling Stations | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | S-9 | S-10 | S-17 | KI-1 | KI-3 | KI-5 | KI-6 | KI-7 | KI-8 | KI-9 | KI-10 | KI-11 | KI-12 | RF-1 | RF-2 | RF-3 |
| | (Organisms $m^{-2}$) | | | | | | | | | | | | | | | |
| PORIFERA | 25 | 25 | 275 | 1100 | 190 | 0 | 0 | 10 | 50 | 0 | 0 | 10 | 0 | 10 | 30 | 60 |
| CNIDARIA | | | | | | | | | | | | | | | | |
| Hydrozoa | 25 | 300 | 75 | 380 | 40 | 80 | 80 | 150 | 0 | 10 | 20 | 110 | 40 | 10 | 190 | 450 |
| PLATYHELMINTHES | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| NEMERTEA | 0 | 75 | 0 | 570 | 30 | 0 | 0 | 0 | 50 | 20 | 10 | 100 | 80 | 30 | 30 | 80 |
| NEMATODA | 25 | 300 | 175 | 3540 | 540 | 70 | 10 | 250 | 40 | 50 | 50 | 170 | 30 | 1250 | 310 | 170 |
| ANNELIDA | | | | | | | | | | | | | | | | |
| Polychaeta | 3725 | 8900 | 5875 | 9100 | 3590 | 9390 | 16000 | 12310 | 6270 | 5650 | 3560 | 3790 | 2890 | 2150 | 3330 | 3510 |
| Oligochaeta | 25 | 0 | 75 | 50 | 10 | 10 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 | 0 |
| SIPINCULA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 10 |
| MOLLUSCA | | | | | | | | | | | | | | | | |
| Polyplacophora | 0 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 50 | 40 | 10 | 0 |
| Gastropoda | 25 | 0 | 75 | 300 | 30 | 100 | 20 | 30 | 40 | 10 | 0 | 50 | 100 | 190 | 310 | 200 |
| Bivalvia | 75 | 100 | 0 | 60 | 80 | 0 | 0 | 30 | 80 | 90 | 30 | 100 | 20 | 220 | 430 | 380 |
| Scaphopoda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 20 |
| ARTHROPODA | | | | | | | | | | | | | | | | |
| Pycnogonida | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 |
| Arachnida (Acarida) | 0 | 0 | 0 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Insecta | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Crustacea | 50 | 150 | 125 | 2650 | 200 | 360 | 30 | 60 | 110 | 30 | 30 | 60 | 40 | 380 | 530 | 410 |
| ENTOPROCTA | 0 | 0 | 0 | 40 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| BRYOZOA | 0 | 25 | 1250 | 350 | 0 | 20 | 0 | 130 | 20 | 30 | 20 | 100 | 40 | 110 | 120 | 10 |
| ECHINODERMATA | | | | | | | | | | | | | | | | |
| Ophiuroidea | 0 | 0 | 0 | 30 | 0 | 0 | 0 | 10 | 10 | 0 | 10 | 20 | 0 | 50 | 210 | 60 |
| Holothuroidea | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 90 | 50 | 60 |
| UROCHORDATA | | | | | | | | | | | | | | | | |
| Ascidiacea | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 |
| Unidentified eggs and larvae | 0 | 50 | 0 | 560 | 10 | 0 | 0 | 0 | 430 | 0 | 0 | 0 | 0 | 0 | 10 | 100 |
| Total organisms $m^{-2}$ | 3975 | 9875 | 7925 | 18360 | 4710 | 10030 | 16060 | 13030 | 6670 | 5890 | 3730 | 4540 | 3320 | 4540 | 5590 | 5450 |
| Total number of taxa | 8 | 8 | 8 | 16 | 9 | 7 | 4 | 12 | 9 | 8 | 8 | 12 | 10 | 13 | 14 | 15 |

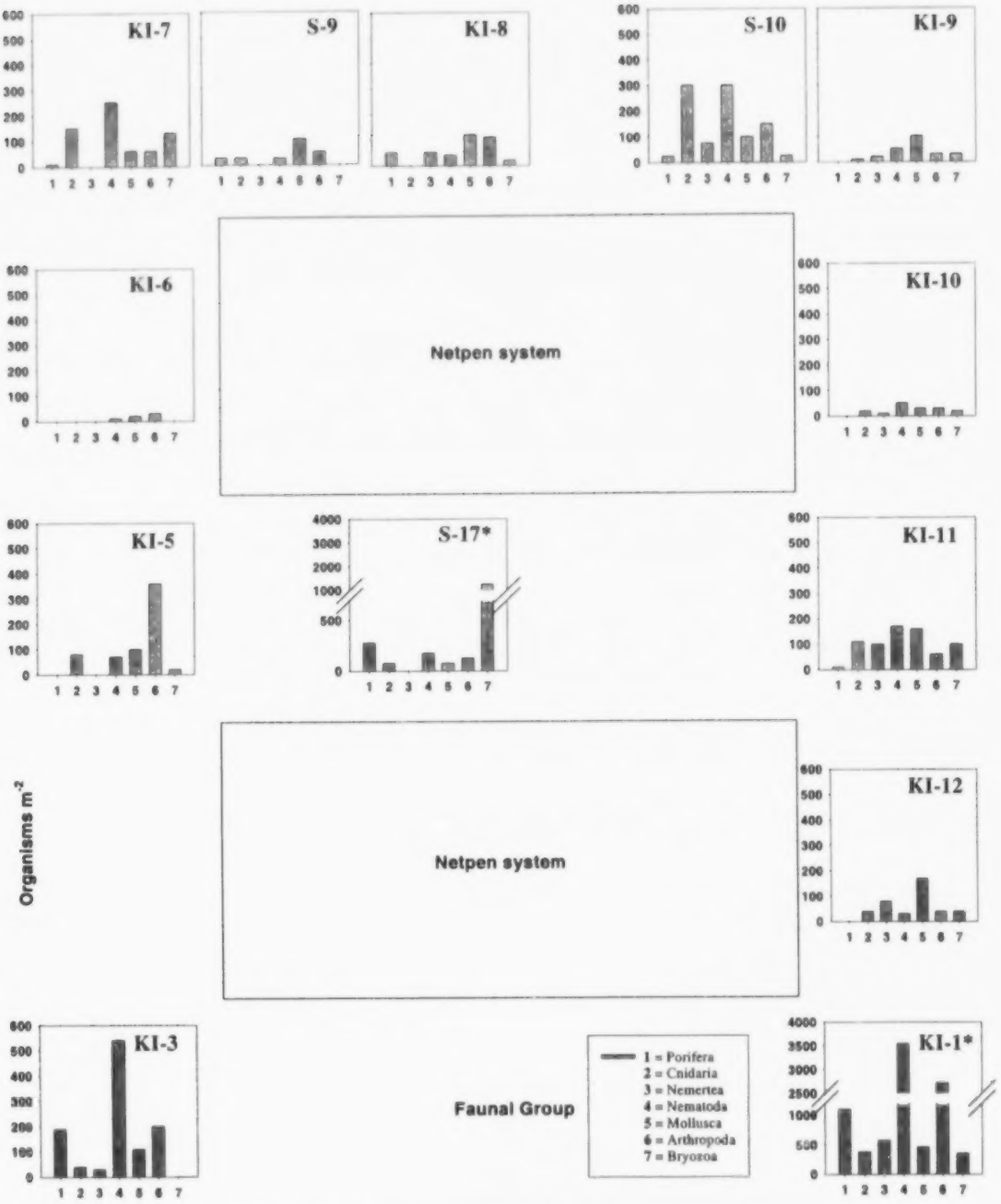


Figure 10. Macrofaunal abundance (annelids excluded) found at farm sampling stations at Kent Island, British Columbia. *Note: stations S-17 and KI-1 standardized to 4000 to accomodate larger range.

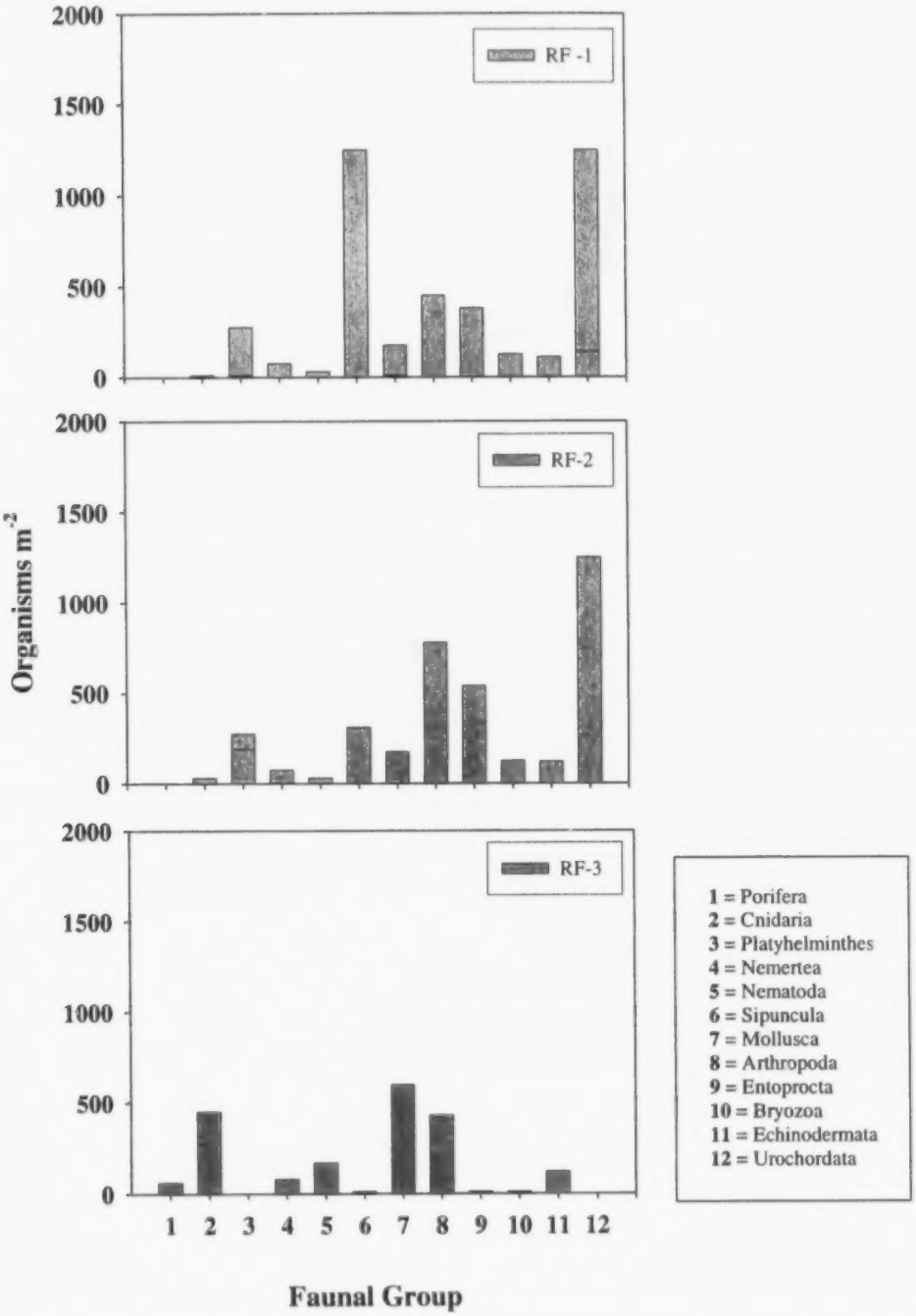


Figure 11. Macrofaunal abundance (annelids excluded) found at reference stations at Kent Island, British Columbia.